SEX RATIOS IN FŒTAL CATTLE.

F. M. JEWELL.

I. Introduction.

It is a matter of common knowledge that among animals there is an approximate equality of numbers between the sexes, and the possible causes for this equality have long been a matter of speculative interest. Since the dimorphic character of the spermatozoa in various animals including cattle (Wodsedalek '20) has been confirmed by many investigators, it is generally conceded that the sex is determined as soon as the successful spermatozoön enters the ovum.

Therefore, according to the laws of chance, one would expect to find an equality of sexes at the time of conception. However, a vast amount of evidence shows that this is not the case, but that throughout the animal kingdom, with few exceptions, there is a preponderance of males at birth.

In the collection of twins in fœtal cattle used by Dr. F. R. Lillie in his work on the free-martin, the sex ratio was 134 males to 100 females and although the total number was but 108, this represented such a wide departure from the sex ratio at birth, as given by other investigators, as to demand attention. This indicates that there may be either a marked difference in the sex ratios in the fœtal and the born population, or that there is some interference in the chance determination of sexes in dizygotic twinning in cattle.

This investigation was undertaken to determine the fœtal sex ratio in cattle in order that this discrepancy might be cleared up, but more particularly to procure data for comparison of the primary, secondary and tertiary sex ratios as stated by A. M. Schultz ('18).

First it will be necessary to give a statement of the existing data on sex ratios in cattle, expressed as the number of males per 100 females.

Wilckens ('87) gives the ratio in cattle at or near the time of birth as 107.3, the number of individuals being 4,900. Pearl and Parshley ('13) in their studies on the sex ratio in cattle in relation to coitus and the period of œstrus give the ratio as 113.3 in a total population of 480. In more recent data by Pearl ('17) covering 1,313 individuals the sex ratio was 100.12.

It should be pointed out that in other animals the data shows that there is no correlation between the sex ratio and multiple births. Parker and Bullard ('14) and also Wentworth ('14) have shown this to be true for pigs; King and Stotensburg ('15) for rats, and Newcomb ('04) showed that in man the sex ratio in twins was practically the same as in single births.

It should be understood that a different rate of mortality in the sexes either during intrauterine development or after birth would cause the sex ratio to vary at different ages, and for this reason the sex ratio is usually spoken of as primary, secondary and tertiary. The primary is the ratio determined at conception and is the original sex ratio; the secondary is that at time of birth and the tertiary during adult life.

A. M. Schultz ('18) attempted to determine the primary sex ratio for man in an indirect way from the data on the mortality of embryos and fœtuses combined with the sex ratio at birth. In doing this he stated that only in case the mortality of the two sexes was equal would the primary and the secondary sex ratios be equal; that if the male and female abortions were absolutely equal, the sex ratio would be smaller at conception than the secondary, and that if there were a greater intrauerine mortality for males than for females, then the primary sex ratio would be greater than the secondary in proportion to the number of abortions and stillbirths.

In order to determine the primary sex ratio, he ascertained the sex ratio in abortions and stillbirths, and the number of such cases for every 100 living born, both male and female. From the data as given by various writers and from the material that he used (nearly 600 fœtuses of the embryology department of Carnegie Institution) he established the following probable values:

For each 100 living born with sex ratio of	105.5
8th to 10th month—4 stillborn, sex ratio of	130.0
4th to 7th month—9 abortions, sex ratio of	106.3
0 to 3d month—14 abortions, sex ratio of	125.0
Total conceptions, 127, sex ratio	"X"

Thus, for every 100 living born he concluded that there were 127 conceptions; 100 with a sex ratio of 105.5, and "a" stillbirths and abortions with a sex ratio "b," in all with a primary sex ratio "X." This primary sex ratio he found to be 108.47. Schultz also quotes the determination arrived at by other investigators as follows: Bernoulli, 108.2; Gendrassiks, 108.2; Lenhossek, 111; Auerbach, 116.4 (who believed that it would reach 125 if certain corrections could be made). Schulze thought that it would not exceed 110.

It was more especially in relation to the primary sex ratio and to determine whether there was a different viability in the male and female fœtuses in cattle that the present investigation was undertaken and with these facts as a basis the data obtained are presented. Special acknowledgment is due Dr. F. R. Lillie, who suggested the problem and gave valuable assistance in the interpretation of the data.

II. Data.

A. *Method.*—The work in collecting was done at one of the large packing plants in Chicago during the spring of 1919. In butchering the cattle at the plant, every uterus containing an embryo is taken to a certain room and if the calf is large enough, the skin is saved. Thus the writer was able to open the uteri and record the data directly as each fœtus was removed. In this way any errors or neglect in birth registration are avoided.

The data embraces 1,000 individuals and the sex and length, as an indication of age, were recorded. Observations were also made on the number of corpora lutea in every case where this was possible, especially when twins wete found, in which case the position in the uterus also was noted. The complete tabular list with the crown-rump measurement and sex of each individual as removed from the uterus is omitted in this article.

B. *Items of General Importance.*—In regard to the number of corpora lutea, in all of the ovaries examined, about 300 in all,

they corresponded in number to the number of fœtuses with one exception. This exception was a pair of identical twins from one ovum, and since we are concerned with the sex ratio at the time of conception, obviously only one of these should be recorded in the data. In this case both ovaries were present, there was only one corpus luteum, and the twins of course were in one horn of the uterus and both of the same sex. This case of monozygotic twins is of very rare occurrence in cattle, being the first observed in the collection of 108 twins in the Zoölogy Department of the University of Chicago. There were four pairs of twins in the 1,000 fœtuses, and as is commonly the case in twins of opposite sex, the male is usually a little farther along in development than the female. In numbers 646 and 647 the male was 3.5 cm. longer than the female, the latter being 65.0 cm. long. In 807 and 808 the males were both the same length, 68.5 cm. In 988 and 989 the male was 6.1 cm. longer than the female, the latter being 58.2 cm. long.

Twins Numbers 648 and 647 and also 807 and 808 were in separate horns of the uterus and there was one corpus luteum in each ovary; while numbers 988 and 989 were in one horn of the uterus and there were two corpora lutea in the ovary of that side. Since the ovaries on some days were removed for commercial purposes before I had access to them, it was impossible to obtain data of this kind on the total of 1,000 fœtuses.

C. *Analysis of Data.*—Since the length of the embryo can be used as an indication of its age, we can arbitrarily make certain groupings and assume that those within that group are on the average at about the same age.

In Table I. is given such a grouping according to length, from 0–10 cm., 10–20 cm. etc., up to 90–100 cm. The smallest individual was 4.2 cm. in length and the largest was 95.3 cm. in length. Thus the data extends from a comparatively early period in fœtal development practically to the time of birth.

The lengths of embryos were tabulated in lots of 50 in order to get some idea of how the sex ratio would vary according to the position of the group in the total of 1,000 fœtuses. Thus in the first space in Table I. are given the inividuals from no. 1

Table I.

The Fœtuses Grouped According to Length. The left-hand column gives the group number in lots of 50. The lowest space gives the totals for the individuals of given lengths.

	0–10		10–20		20–30		30–40		40–50		50–60		60–70		70–80		80–90		90–		
Group.	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	Total.
1.....			1	2	3	2	4	2	1	2	1	3	8	7	4	4	2	4			50
2.....	1		4	1	5	2	5	1	3	3	2	1	1	5	5	7	3	1			50
3.....	2		3	2	2	5		2	1	4	4	3	4	4	6	5	2		1		50
4.....			1		2	2	4	2	4	5	4	1	2	4	7	8	3		1		50
5.....			2	1	5	4	6	1	6	2	2	3	6	3	3	3	2		1		50
6.....	1		1	3	1	2	5	3	2	3	2	3	7	2	6	4	3	2			50
7.....			4	3	5	2		3	4	3	6	4	5	1	6	3	1				50
8.....			5	3	5	3	3	3	5	4	2	4		1	6	2	2	2			50
9.....				4	4	2	7		3	4	2	7	4	3	3	5	1	1			50
10.....	1	2	6	1	3	2	4	5	2	1	6	1	5	2	1	3	2	3			50
11.....	1		4	2	4	5	4	2	4	7	5	4	2	3	1	1			1		50
12.....			2	1	4	6	5	7	7	1	5	1	3	3	3	2					50
13.....			3	2	1	1	4	4	2	2	6	2	7	5	3	5	1	2			50
14.....				2	3	9	5	3	4	5	2	1	4	4	2	1	4			1	50
15.....		1	1	1	5	2	5	3	3	1	4	2	6	3	5	2	3	3			50
16.....			3	3	4	9	6	9	3	2	2	1	3		1		2	2			50
17.....				2	5	3	2	4	6	2	3	4	5	1	2	6	1	4			50
18.....	1	1	7	4	6	6	4	1	3	4	2	2	2	2	1	1	2	1			50
19.....	2		6	3	5	4	6	1	2	3	3	1	1	5	1	1	3	3			50
20.....	2		3	1	5	4	5	5	4	3	3	4	5	2	2	2					50
Total..	11	4	56	41	77	75	84	61	69	61	66	52	80	60	68	65	37	28	4	1	1000

to 50; next, from 50 to 100; 100 to 150 and so on. In the column to the extreme right is given the total for each space as a check on the number of individuals, the total for all spaces being 1,000. The group totals for different lengths, given in the lowest space, show the males without exception to be more numerous than the females, although in the 20–30 group the sexes approach equality. In all, there are 552 males and 448 females, giving a sex ratio of 123.21. If the sex ratio for each of these groups is determined we get the following values (Table II.):

It is obvious that in the 0–10 group and the 90–100 group the number of individuals, 15 and 5 respectively, is too small to be considered separately, especially since the sex ratio in each case is so extremely high. In the 10–20 group the sex ratio of 136.5 is well above the sex ratio of 123.21 for all individuals, while in the 20–30 group it has fallen to 102.6. Then in the next four groups from 30 cm. to 70 cm. the average sex ratio is 127.75.

Therefore, the results in the 20–30 group are very peculiar and can be interpreted only as due to chance, even though the number within that group is 152 individuals. It would be impossible for the males to reach again such a preponderance as 127 to 100 females after such a differential elimination of the sexes as would appear to be indicated in the 20–30 group, if there were such a high mortality of males in that group.

Table II.

Showing Sex Ratios According to Length.

Length.	Sex Ratio.	Number of Individuals.
0– 10	275.0	15
10– 20	136.5	97
20– 30	102.6	152
30– 40	137.7	145
40– 50	113.1	130
50– 60	126.9	118
60– 70	133.3	140
70– 80	104.6	133
80– 90	132.1	65
90–100	400.0	5

If the sex ratios are computed for individuals up to a certain length on the one hand and then for all over that length, a comparison can be made of the ratios for *relatively* younger and older fœtuses. In this way if there is any difference in the viability of the sexes we should expect to find that in the younger fœtuses the sex ratio would be high and that there might perhaps be a critical age, as indicated by length, in which there would be a greater mortality for one sex than for the other. We should also expect to find that after this critical stage in development is past the sex ratio in the remaining groups would not vary so greatly from the total of 123 as it did up to that group.

Table III. gives such a grouping with the number of individuals and the sex ratio for each group. The advantage of greater numbers within the group is also gained in this way. The sex ratios in this table were computed from the complete tabular list.

Thus, it is noted that for 112 individuals up to 20 cm. the sex ratio is 148.88 and that for the remaining 888 individuals from

Table III.

Showing a Comparison of the Sex Ratios of Relatively Younger and Older Fœtuses.

Length.	Individuals.	Sex Ratio.	Length.	Individuals.	Sex Ratio.
0– 20....	112	148.88	20–100	888	120.34
0– 30.....	264	120.00	30–100	736	124.39
0– 40.....	409	125.96	40–100	591	121.34
0– 50.....	539	123.14	50–100	461	123.78
0– 60.....	657	123.46	60–100	343	122.72
0– 70.....	797	125.14	70–100	203	115.95
0– 80.....	930	121.95	80–100	70	141.37
0– 90.....	995	122.50	90–100	5	400.00
0–100.....	1,000	123.21			

20–100 cm. the sex ratio is 120.34. The objection may be raised, and quite rightly, that 112 is too small a number on which to base definitely the sex ratio for individuals from 0–20 cm., especially since, when the next group of individuals from 20–30 cm. is included, the sex ratio from 0–30 cm. becomes lowered to 120.0. However, it should be pointed out that in the 20–30 cm. group, there is a relatively low sex ratio of 102 when compared with the total of 123, and that this is probably due to chance. When this is taken with the sex ratio of the 0–20 cm. group with a sex ratio of 148, it of course lowers it considerably and the reverse is true for the individuals above that length. Thus, the groups from 30–100 cm., being relieved of the burden of the 20–30 cm. group, have a combined sex ratio of 124.39. This no doubt partly explains such discrepancies as appear in passing from the 0–20 cm. to the 20–30 cm. groups, and in the 20–100 cm. and the 30–100 cm. groups. If the 20–30 cm. group had been such that it could have been considered practically normal, the wide and suddenly marked differences here shown probably would not exist.

However, it might be suggested that, although the sudden drop in the number of males in the 20–30 cm. group may represent a chance occurrence, it might be that this is the critical period in embryonic development in which there is a greater viability in the female fœtuses and that the normal sex ratio for this group might well be below the average of 123.

In the 0–40 cm. group the sex ratio of 125.96 shows a greater

sex ratio than in the 40–100 cm. group with a sex ratio of 121.34, and here again, as in all succeeding cases, the 20–30 cm. group tends to lower the sex ratio for the relatively younger individuals. In the 0–50 cm. and the 50–100 cm. groups there is an approximate equality between the sexes, being 123.14 in the former and 123.78 in the latter case. The sex ratio of the groups, at which so close an approximation is reached, is also practically the same as the sex ratio of 123.21 for the total number of individuals. The same is practically true of the 0–60 and the 60–100 groups with a sex ratio of 123.46 and 122.72 respectively. In the 0–70 cm. group with 797 individuals, there is a slight rise in the sex ratio (125.14) and for the 70–100 cm. group with 203 individuals the ratio is 115.95. In the group from 0–80 cm. with 930 individuals the sex ratio of 121.95 of course approaches the average and in the 80–100 cm. group with only 70 individuals there is a sex ratio of 141.37, which can, in so small a number, likewise be considered as due to chance. From 0–90 cm. with 995 individuals the sex ratio is 122.5 and the remaining five have a sex ratio of 400.

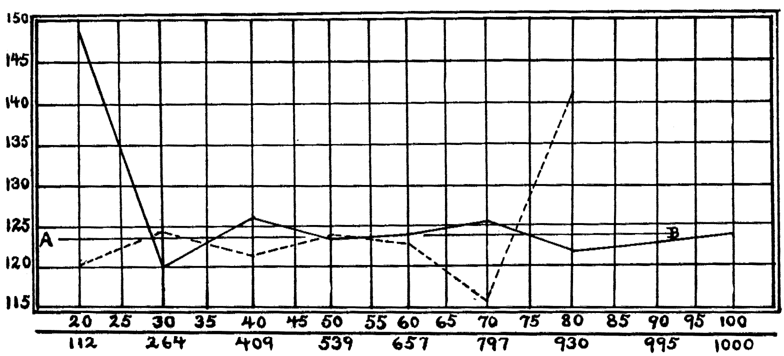

FIG. 1. Representing graphically the sex ratios for relatively younger and older fœtuses. The values for the sex ratios are indicated on the ordinate and the lengths on the abscissa. The number of individuals in each case is given below the lengths. Those below the dividing line (relative to length) are indicated by the continuous line, those below that length by the dotted line.

This is represented graphically in the following figure (Fig. 1) in which the fœtuses below the dividing line (relative to length) are shown by the continuous line.

The values for the sex ratio are indicated on the ordinate and

the lengths of the individuals on the abscissa. The number of individuals dealt with in each case is given below the length. From 30 cm. and upward the highest point is 125.96 in the 0–40 cm. group, and the lowest is 120 in the 0–30 cm. group. The average sex ratio from 30–100 cm. is 123.27 as indicated by the line AB and the average deviation in this group is therefore 2.88.

If the line for all individuals over certain lengths is plotted in conjunction with those below the same lengths, the relative sex ratios for the groups compared can be seen. This is done in Fig. 1, the values being taken from Table III. From this figure it will be seen that on the average the dotted line runs below the heavy line, the former representing the individuals above the lengths indicated and the latter being those below the same lengths. The exceptions to this are in the 20–30 cm. group and the 80–100 cm. group with a sex ratio of 141, which includes only 70 individuals.

Therefore it would seem that in the younger stages there may be a slight difference in the viability of the two sexes, the male being somewhat more susceptible to intrauterine disturbances. However, this difference does not seem to be constant enough to be of real significance and one could not, from the data given here, conclude with certainty that in the fœtal development in cattle there is a greater mortality in the males during any particular developmental stage. A larger collection of individuals within each group would no doubt clarify the situation, although with all groups considered together, the sex ratio of 123 is probably very near to the true value.

Discussion.

A. Reasons for Discrepancies Between the Primary and Secondary Sex Ratios in Cattle

1. *A Possible Differential Viability.*—The only data for the secondary sex ratio with which we can compare the ratios during fœtal development are those of Wilckens ('87) who places the secondary sex ratio at 107.3; Pearl and Parshley ('13) who find it to be 113.3 in a population of 480, and Pearl ('17) who finds it to be 100.12 in a population of 1,313 individuals.

If we can compare the data obtained during fœtal development with that given above as the ratio at birth, it will be noticed that the former on the whole, with a sex ratio of 123.21, is well above the secondary ratio. Since in all of these cases the data include various breeds, it is fair to compare them in this respect. It would thus appear that there is a greater mortality among the male fœtuses, for only in this way would the sex ratio at birth be less than that during fœtal development. The figures as they stand in the present article, however, do not show sufficiently well-marked evidence to support the supposition that there is a greater mortality among the males at any particular stage of development.

2. *Possible Variations in Different Populations or Breeds.*—During the summer of 1919 correspondence was carried on with a large number of breeders to obtain data for comparison of the sex ratio at birth with the ratio during fœtal development, and also to determine the influence, if any, of the breed on the sex ratio. The Short Horn was taken as the beef type and the Holstein-Friesian as the dairy type of cattle. Only registered cattle were used and the data included the sire's name and number, the year, and the number of male and female calves by that sire. The total results of this investigation are given in Table IV. Data were also obtained in reference to twins of the same sex and of opposite sexes.

TABLE IV.

SHOWING THE SEX RATIOS FOR SHORT HORNS AND HOLSTEIN-FRIESIANS.

	Short Horns.			Holstein-Friesians.		
	Males.	Females.	Ratio.	Males.	Females.	Ratio.
Single births	862	881		958	978	
Pairs of twins of same sex	2	2		15	17	
Pairs of twins, opposite sex	8			18		
Single births and twins of opposite sex	870	889	97.86	976	996	97.99
Total, including all twins	874	893	97.87	1,006	1,030	97.66
Grand total, both breeds	Males 1880; females 1923. Sex ratio, 97.76					

From this table it will be seen that the total number of single

births and dizygotic twins in the Short Horns included 870 males and 889 females with a sex ratio of 97.86. The corresponding group in the Holstein-Friesians contains 976 males and 996 females with a sex ratio of 97.99.

In the Short Horns the total including the twins of the same sex, a very few of which *might* have been monozygotic, there are 874 males and 893 females, the ratio being 97.87. The corresponding group of Holstein-Friesians contains 1,006 males and 1,030 females with a sex ratio of 97.66.

The total in both breeds was 1,880 males and 1,923 females, making a total population of 3,803 with a sex ratio of 97.76.

Thus it will be seen that there is no marked variation in the sex ratios of the two breeds, the two in fact approximating each other very closely.

It is possible that in a mixed population there might be a change in the sex ratio as has been indicated by various investigators in data on hybridization. Guyer ('09) found a great excess of males among hybrid pigeons and suggested that "more or less default in the metabolic processes because of the incompatibilities which must necessarily exist between two germplasms so dissimilar" would lead to a production of more males.

M. Pearl and R. Pearl ('08), in comparing pure with cross matings for man in Buénos Ayres, showed a "significantly greater proportionate production of males in the offspring from matings involving different racial stocks than in the offspring from matings in which both parents belong to the same racial stock."

Unusual sex ratios might result in hybridization of breeds of cattle that were unlike in respect to the size of the fœtus. An extreme case illustrative of this would be the bison-cattle crosses. Babcock and Clausen point out that practically all of the offspring of this cross are females due to the increased size of the hybrid fœtus and the consequent abortion or death of the male fœtuses. Thus, sex eliminating factors, as in this case, would change the secondary sex ratio.

Wilckens found that in the "Niederungsrassen" the sex ratio was 114 in 3,009 individuals as compared with an average ratio of 107.3.

3. *Errors in Sampling.*—It is also probable that errors might be made in sampling in the secondary and tertiary sex ratios. This might be done quite unconsciously by farmers, due to failure to record the sex promptly at birth. Some farmers might be prejudiced in favor of one sex and if the calves of the other sex should die before registration they probably would not be entered.

From this viewpoint one might compare the discrepancies in data on the sex ratios in cattle as given by various investigators, ranging from 97.76 (in Table IV. above) to 107.2 in the data of Wilckens and 113.3 as given by Pearl and Parshley.

Numbers Involved.—The question might be raised as to whether the number of fœtuses, 1,000, would represent a small enough number to make a material difference in the sex ratio as compared with a much larger number. Considering the sex ratio in the larger groups of fœtuses when grouped according to length it would appear that the sex ratio for the total collection, 123.21, is very near to the true one during fœtal development in cattle.

B. *Association of Sexes in Fœtal Twins.*

The data indicates that the sex ratio of 134 for dizygotic, fœtal twins, as found by Dr. F. R. Lillie, is not far from the normal of the population and therefore the association of sexes in twins is presumably a random sampling.

Conclusions.

1. The sex ratio during fœtal development in cattle is 123.21
2. This sex ratio of 123.21 during fœtal development compared with the much lower sex ratios at birth indicates a greater mortality of males during intrauterine development.
3. When compared with the sex ratio of 123.21 the sex ratio of 134 in F. R. Lillie's collection of twins in fœtal cattle does not indicate any interference with the chance assortment of sexes in dizygotic twinning in cattle.
4. The data do not indicate that there is any particular stage in development during which there is a more marked mortality among the males than in any other stage.
5. There is no indication that the breed causes any variation in the sex ratio.

6. Discrepancies between the primary and secondary sex ratios in cattle, excepting errors of sampling, are due to sex eliminating factors rather than factors that effect the primary sex ratio.

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